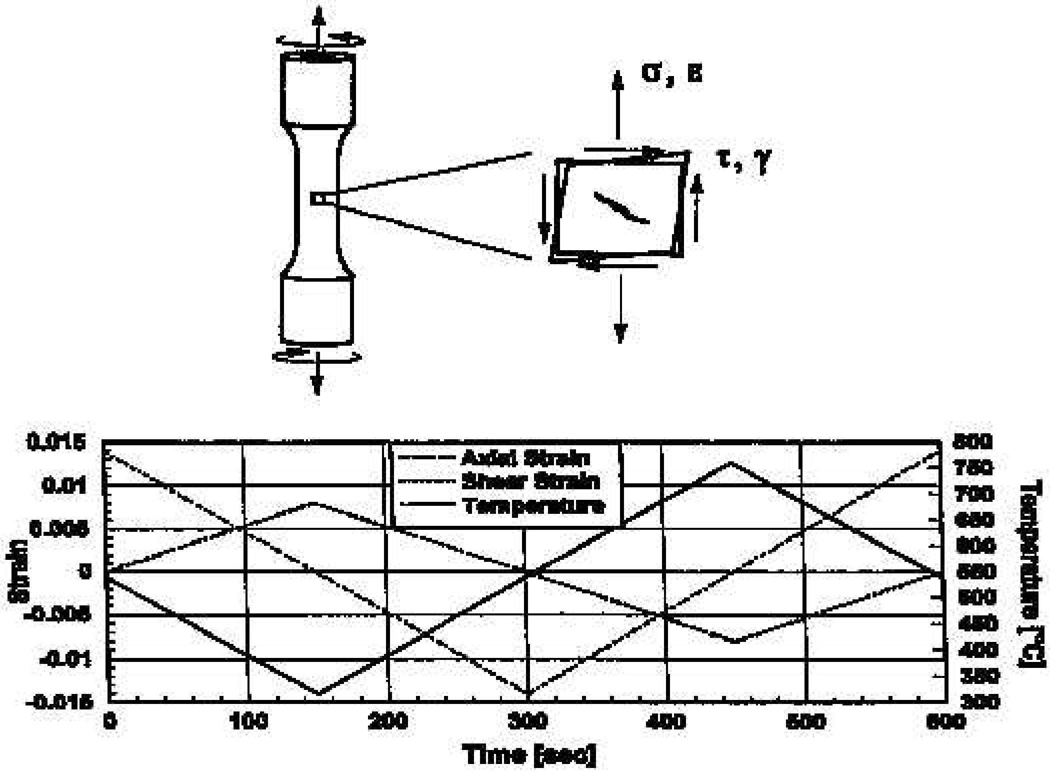
Thermomechanical Multiaxial Fatigue Testing Capability Developed

Structural components in aeronautical gas turbine engines typically experience multiaxial states of stress under nonisothermal conditions. To estimate the durability of the various components in the engine, one must characterize the cyclic deformation and fatigue behavior of the materials used under thermal and complex mechanical loading conditions (refs. 1 and 2). To this end, a testing protocol and associated test control software were developed at the NASA Lewis Research Center for thermomechanical axial-torsional fatigue tests. These tests are to be performed on thin-walled, tubular specimens fabricated from the cobalt-based superalloy Haynes 188. The software is written in C and runs on an MS-DOS based microcomputer.

Innovations incorporated into the test control software include a successive approximation algorithm for constant-rate temperature control, dynamic compensation for the coefficient of thermal expansion times the temperature change changes in the specimen dimensions (including the extensometer gage length), synchronization of all command and acquisition events with the microcomputer's 8254 timer chip, high data-acquisition-rate oversampling to reduce noise while minimizing signal time averaging, polynomial interpolation of temperature versus thermal strain, and control of the axial mechanical strain (total strain minus the product of the coefficient of thermal expansion and the temperature change). In addition, to avoid crack initiation from thermocouple spot welds, the gage section temperature is monitored by a light pipe infrared probe. The test control software allows for arbitrary phasing between the temperature, the axial command waveform signals, and the torsional command waveform signals. Axial and torsional load, strain, and stroke, as well as specimen temperature data, are acquired 1000 times per cycle. Tests are performed in 600-sec cycles (dictated by slowest free-convection cooling rate at the low end of the temperature cycle). Graphical output of axial and torsional stress response, temperatures, and additional pertinent information are displayed on the computer monitor in real time.

The test matrix will include (1) axial in-phase and axial out-of-phase thermomechanical fatigue (TMF) tests, (2) torsional in-phase TMF tests, (3) mechanically in-phase and thermally in-phase tests, (4) mechanically in-phase and thermally out-of-phase tests, (5) mechanically out-of-phase and thermally in-phase tests, and (6) mechanically out-of-phase and thermally out-of-phase tests. The maximum and minimum temperatures for all tests will be 760 and 316 °C, respectively. Results will be used to assess multiaxial fatigue life models for their applicability to cyclic thermomechanical loading conditions. This program has been preceded by baseline experiments establishing the axial-torsional fatigue and deformation characteristics of Haynes 188 at 760 and 316 °C.



Axial-torsional thermomechanical fatigue. Top: Schematic. Bottom: Mechanically out-of-phase and thermally out-of-phase cycles.

References

1. Kalluri, S.; and Bonacuse, P.J.: Estimation of Fatigue Life Under Axial-Torsional Loading. PVP-Vol. 290, Material Durability/Life Prediction Modeling: Materials for the 21st Century, S.Y. Zamrik and G.R. Halford, eds., ASME, 1994, pp. 17-34.

2. Bonacuse, P.J.; and Kalluri, S.: Cyclic Axial-Torsional Deformation Behavior of a Cobalt-Base Superalloy. NASA TM-106372, 1994, pp. 204-229.